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A COMPUTATIONAL AND EXPERIMENTAL INVESTIGATION OF VIOLENCE IN A THERMAL EXPLOSION TEST (U)†

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Oral presentation requested
Applications

We are developing computational models and making measurements for violence in a thermal explosion test involving an HMX-based explosive (LX-10) and a high strength AerMet 100 steel. The thermal response of explosives is relevant to accident scenarios involving fires. The Navy is interested in the behavior of munitions exposed to shipboard fires to help with the design of storage systems and the development of fire fighting strategies.

In thermal explosions, time scales for behavior can range from days to microseconds. During the relatively slow heating phase, the response of an energetic materials system is paced by thermal diffusion and chemical decomposition, while the mechanical response is essentially a quasi-static process. As the decomposition reactions accelerate, heat is generated faster than it can diffuse. Product gases are formed and the rising pressure accelerates the energetic and containment material. The resulting violence can range from a pressure rupture to a detonation.

We use the ALE3D code to model a Scaled Thermal Explosion Experiment (STEX). A 5.08 cm diameter X 20.32 cm high explosive is confined in a steel tube and heated at a 1°C/h rate until explosion. In an earlier study, the thermal/chemical/mechanical response of RDX-based explosives was analyzed by comparing the calculated results with the measurements. The time-to-explosion was accurately predicted while simulations for the wall expansion captured many features of the wall strain measurements.

A computational and experimental effort is in progress to measure fragmentation of an AerMet100 steel tube that initially confines LX-10. Thermocouples are used to monitor the temperature of the steel case and the internal heating of the explosive as it decomposes. Strain gauges provide measurements of the tube expansion due to heating, pressurization from HE decomposition, and the rapid burn of the explosive. Metal fragment velocities are measured with velocity

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probes and a radar system. Captured fragments are used to establish size distributions and fracture characteristics.

Preliminary ALE3D calculations show a fracture patterns on a tube that has been pressurized by the deflagration of the confined explosive. Fragments separate as elements of failed metal deform and propagate (see figure below). A 4-step reaction model is used for the decomposition of HE into product gases. The solid HE species are modeled as isotropic elastic-plastic materials with 7-term polynomial equations of state. For the gaseous species, we use the gamma-law equations of state. For the AerMet 100 steel, we use the Gruneisen equation of state, and the shear modulus and the yield strength that vary with pressure, temperature, and equivalent plastic strain. The modified Johnson-Cook failure model is employed with a specified distribution of failure strains to provide for fracture initiation. Comparisons are made for model and measured tube expansion rates along with fragment sizes and velocities.

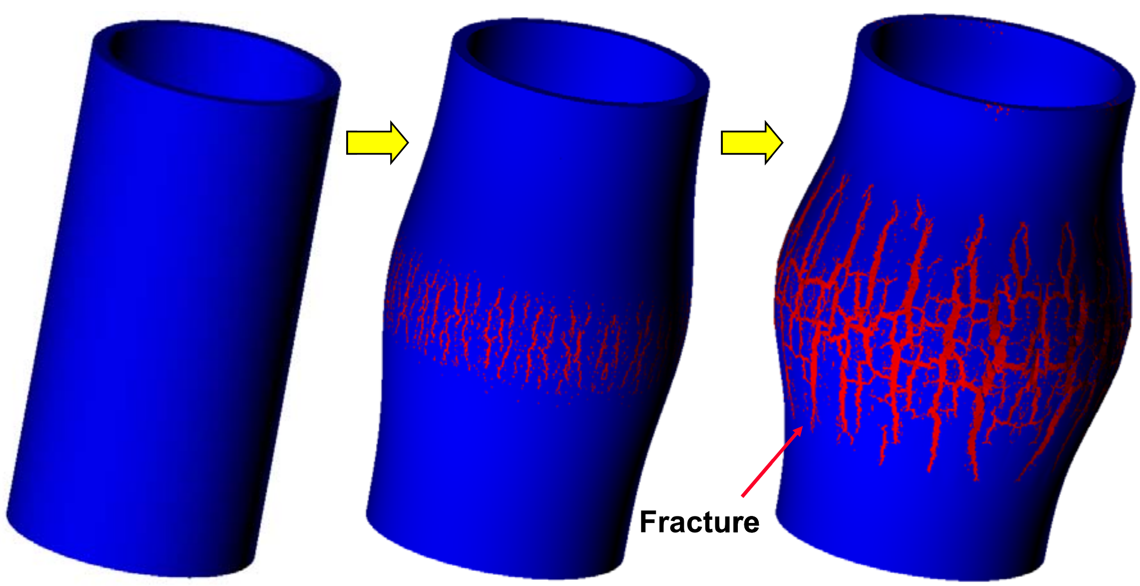

Figure 1. AerMet 100 steel pipe expanding and fracturing as LX-10 burns in the interior. Tube dimensions (3 mm thick X 2 inch OD X 4 inch L). Resolution (1 million elements, $\Delta x = 250\ \mu m$).